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Effect of Seed-Placed Ammonium Sulfate and Monoammonium Phosphate on Germination, Emergence and Early Plant Biomass Production of Brassicae Oilseed Crops

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1. Introduction

Seed-placed fertilization, in which fertilizer is placed in the soil in the same furrow as the seed at the time of planting is a common approach to supplying crop nutrients, as this gives newly emerged seedlings early access to nutrients. This placement strategy is noted to be effective for phosphorus fertilizer due to its low mobility in the soil in early spring (Miller et al., 1971; Harapiak, 2006). In the prairies of Canada, cool soil temperatures in the spring at seeding can especially restrict early root growth and access to phosphorus. Therefore it is important for annual crops to be able to access P early in their growth cycle by placing P fertilizer where the roots of the seedling can readily access it, such as in the seed-row. This is the reason why seed-placed phosphorus fertilization normally achieves better response than surface-applied with incorporation. Lauzon and Miller (1997) reported that early season corn and soybean shoot-P concentrations are increased with increasing soil test P and were increased with seed-placed P regardless of soil test P level. However, the germination and emergence of crop seeds can be reduced by seed-placed phosphate fertilizer, as some crop seeds are especially sensitive to the salt effect of fertilizers (Qian and Schoenau, 2010).

In western Canada, canola is a major crop and approximately 4.5 million hectares of agricultural land are under *Brassica* oilseed crop production (Malhi et al., 2007). Canola-quality *B. juncea*, *B. carinata*, and oilseed *Camelina sativa* are also being developed as alternative oilseed crops that are better adapted to areas with periods of hot, dry conditions in western Canada. Tolerance of *Brassica* crops to seed-row application of nutrients is low when compared to many other crops, and emergence differences have been observed between open-pollinated and hybrid cultivars (Brandt et al., 2007). Differences have also been noted in the tolerance and responsiveness of yellow- and black-seeded canola cultivars to seed-placed P (Grant, 2008). Qian and Schoenau (2010) reported that canola seed, in general, is sensitive when the seed-placed rate of P is above 30 kg P_2O_5 ha^{-1}. The development and adoption of maximum safe rates of fertilizer with seed that avoid significant reductions in crop emergence is important for achieving maximum benefit from the fertilizer by producers.

Brassica crops like canola have higher demand for S than cereal crops. Canola requires about twice the amount of sulfur as cereal crops do, and canola frequently responds to fertilizer S addition in the drier rain-fed cropping areas of the prairie provinces of Canada, where no-till cropping systems are predominant (Canola Council of Canada 2010). A balance in availability of N, S and P for canola is important for both canola yield and quality (Janzen and Bettany, 1984; Jackson, 2000; Karamanos et al., 2005, Qian and Schoenau, 2007). In Canada, the main S fertilizer used is ammonium sulphate (21-0-0-24). Ammonium sulphate, both as prills and as fines, has become a popular source of N and S fertilizer for canola growers. Given the increased prevalence and availability of ammonium sulfate originating as by-products of industrial processes such as flue gas scrubbing, it seems likely that ammonium sulfate will be cost-effective and its use is likely to increase in the future. However, to date there has been little attention given to the tolerance of Brassica crops like canola to seed-row placed ammonium sulfate, both alone and in combination with starter phosphorus. Also, ammonium sulfate has a higher salt index than monoammonium phosphate and can produce significant amounts of free ammonia, leading to the possibility of both osmotic damage and direct ammonia toxicity at high application rates (Follett et al., 1981). Therefore, providing guidelines for maximum safe rates of fertilizer P and S with the seed is essential for achieving maximum benefit from seed-row placement of fertilizer. Current guidelines state that the amount of S that can be safely placed with the seed of canola as ammonium sulfate should be based on N guidelines, and no specific information is provided on tolerance and response to combinations of ammonium sulfate and starter monoammonium phosphate. Nevertheless, existing guidelines were developed some time ago based on seeding equipment with high disturbance and high seed-bed utilization. The trend today is towards low disturbance opener systems. Growers have questioned how much ammonium sulfate can be safely placed in the seed-row along with P as a starter blend for canola, especially with low soil disturbance opener configurations currently used. The objectives of this chapter are to: (1) determine the effects of seed-placed ammonium sulfate (AS) and monoammonium phosphate (MAP) fertilizer applied at different rates on seedling germination and emergence as well as early season dry matter yield under controlled-environmental conditions; and (2) determine if *Brassica* oilseed crops/cultivars differ in their response to seed placed S and P fertilizer. To fully achieve these objectives, experimental works were conducted as described below, and results and conclusions are drawn.

2. Methods and materials

2.1 Soil, fertilizer and crop seeds

The soil selected for the study is a Brown Chernozem (US classification: Aridic Haploboroll), loamy textured soil from a long-term alfalfa field (legal location: SW31, Township 20, Range 3, W of 3rd Meridian) in southwestern Saskatchewan, Canada. The soil represents a common soil type (Haverhill association) found in the southern prairies of Saskatchewan. As there was no history of herbicide application, there was no concern with herbicide residue carryover that could affect germination. The soil was collected from the 0-15 cm depth in the fall of 2010 from a field that has been in continuous alfalfa for ten years. The main soil characteristics and nutrient levels are shown in Table 1.

Soil	pH	Organic C	Texture	Available/Extractable			
				NO_3-N	P	K	SO_4-S
		%		mgkg^{-1}			
Haverhill	8.0	2.3	loam	45.7	12.3	693	24.0

Table 1. Some characteristics of the soil used for seed-placed S and P evaluation.

After collection, the soil was mixed thoroughly in a soil mixer and stored in field-moist condition before use. For measuring basic soil properties, a sample was collected from the mixed soil, and then air-dried, crushed, and passed through a 2-mm sieve and stored at room temperature. Texture was estimated by hand. Electrical conductivity (EC) and pH were measured using 1:1 soil:water suspension. Organic C was measured using an

Species and Cultivar	Type	Herbicide system	Year of release	Maturity
B. napus				
5440	HYB	LL	2007	Mid-Late
5525	OP	CL	2009	Mid-Late
45H26	HYB	RR	2006	Mid
v1037*	HYB	RR	2007	Early-Mid
v1040*	HYB	RR	2010	Mid
74P00	OP	LL	2006	Early-Mid
H.E.A.R*	OP	RR		
B. juncea				
Dahinda	OP	Conv.	2004	Late
Xceed 8571	OP	CL	2008	Early
B. rapa				
ACS- C7	SYN-OP	Conv.	2001	Early
Camelina sativa				
Calena	OP	Conv.	N.A.	Early
B. carinata	OP	Conv.	N.A.	Late

*-specialty oil; HYB-Hybrid; OP-open-pollinated; SYN-synthetic; Conv.-conventional
LL-Liberty Link; RR-Roundup Ready; CL-Clearfield

Table 2. Selected *Brassica* species/cultivars used in this study.

automated combustion LECO carbon analyzer. Soil available P and K were extracted by modified Kelowna method (Qian et al., 1994). Soil available N was calculated as the sum of NO_3-N + NH_4-N. Both forms of inorganic N were extracted with 2 M KCl (Keeney and Nelson, 1982) and measured by automated colorimetry. Soil available S was extracted with 0.001 M $CaCl_2$ solution and measured by automated colormetry (Qian et al., 1992). The fertilizer phosphorus source used was conventional commercial fertilizer grade granular monoammonium phosphate MAP (12-51-0). The sulfate source used was fertilizer grade prilled ammonium sulfate $(NH4)_2SO_4$ (21-0-0-24). The *Brassica* species/cultivars selected for this study are listed in Table 2. Among the 12 selected cultivars, four different categories of canola were included: open pollinated (OP) and hybrid *napus* (also termed "Argentine" canola) (HYB), *rapa* (also termed "Polish" canola), and *juncea* (sometimes termed "mustard canola"). Although not currently grown on a large commercial scale, *B. carinata* and *C. sativa* are currently under development as new oilseed crops with similar attributes to canola and were therefore included in the study as well.

2.2 Laboratory study

Plants were grown in plastic trays (52cm x 26cm x 6cm) containing 5.4 kg of uniformly mixed, air-dried soil at 20 degrees C. The soil in each tray was levelled to a height of 5cm over the individual rows and packed. Six 20cm x 2.50cm x 1.25cm seed-rows were created in the trays using a seeding tool. The crops were seeded using a seed quantity per unit area in the row that is equivalent to a seeding rate of approximately 10 kg ha^{-1}. The seeding tool used creates a seed bed utilization of approximately 15%, in which 15% of the total seed bed area is used for placement of seed and fertilizer in rows. This seed bed utilization is typical of the wide row spacing, narrow opener seeding tool configurations commonly used for seeding oilseeds in the northern Great Plains today. Sixteen seeds were seeded in each row at a uniform depth of 1.25cm.

The fertilizer was passed through a 2mm sieve to provide uniform granule size and then spread uniformly down the seed-row with the seed. During germination, trays were kept under constant light and regularly watered to maintain soil moisture at 100% water holding capacity for the first two days and ensure germination, and then reduced to 80% of field capacity to maintain soil moisture for seedling growth. Emergence counts were taken every two days after seeding until 14 days after seeding (DAS) when plant counts were constant and no additional emergence was observed. Plants were harvested 14 DAS. Plant biomass samples were washed in deionized water after cutting at the soil surface and oven-dried at 45°C for 3 d to a constant weight.

Six treatments consisting of an unfertilized control and five rates of seed-placed S (10, 20, 30, 40 and 50 kg S ha^{-1}), applied as ammonium sulfate (AS 21-0-0-24) were applied in combination with three rates of seed-placed P_20_5 (0, 15 and 30 kg P_2O_5 ha^{-1}), applied as monoammonium phosphate (MAP 12-51-0).

The *B*. species/cultivars were designated as main plots, S rates as subplots and P rates as sub-subplots within the trays and were arranged in a randomized complete block design with four replications. Nitrogen was applied at 10, 20, 30, 40, 50 kg N $ha^{-1}$with the ammonium sulfate alone, and with 15 kg P_2O_5 ha^{-1} as well as 30 kg P_2O_5 ha^{-1} in the seed-row.

2.3 Statistical analysis

Main and interaction effects of *Brassica* cultivars and ammonium sulfate, alone and in combination with monoammonium phosphate, were determined from analysis of variance (ANOVA) using the GLM procedure in SAS (SAS Institute, 2008). Least significant difference (LSD 0.05) was used to determine significant differences between treatment means.

3. Results and discussion

3.1 Effect of seed-row placed ammonium sulfate on brassicae emergence and early season biomass

Generally, there was no significant difference in percent emergence up to 20-30 kg S ha $^{-1}$ when ammonium sulfate was applied alone with the exception of *Camelina sativa. Camelina sativa* appeared more sensitive to AS placed in the seed-row than the *Brassica* crops (Table 3). At rates of 30 kg S ha^{-1}, only *Invigor 5440* and *B. Juncea Dahinda* showed inhibition effect. When application rate approached 40 kg S ha^{-1}, the majority of cultivars were affected. The cultivars *HEAR, 5525 Clearfield* and *74P00LL* were the least sensitive to seed-row placement of AS, possibly reflecting greater seed vigor. In general, percentage emergence that dropped below 80% was observed in some *Brassica* cultivars at rates of 30 kg S ha^{-1}, and more so at the rates of 40 kg S ha^{-1} and above (Table 3).

High oleic, low linolenic (HOLL) (*v1037*; *v1040*) were also less sensitive to seed-row placement of AS; however, they were not as resistant as high erucic acid rapeseed (H.E.A.R). The number of days to first seedling emergence increased with increasing S rate. Time to seedling emergence from seeding was approximately 5-7 d. Emergence was generally 1 to 2 d longer in the high S rate treatments. There was a close relationship between seed size and seed coat color and a decrease in percent emergence, with the yellow-seeded and small seeded cultivars slightly more prone to reduced emergence with seed-placed AS. In most cases, the larger the seed size, the better the vigour. The more vigour, the better the seed/seedling is able to cope with early stresses and survive (Canada Canola Council 2005). High rates of AS reduced the seedling emergence, early seedling growth and increased the time to maximum emergence of seeds. There was an increase in the number of abnormal seedlings observed in the higher S treatments due to seedling injury, which can be attributed to the salt effect of the fertilizer playing a major role in this case (Follett et al., 1981).

Seedling biomass yield (mg / pot) at 14 days of growth was not significantly affected up to rates of 20 – 30 kg S ha^{-1} (Table 4). At higher rates in which significant emergence reduction was observed, seedling biomass was also reduced. As Hall (2007) indicated, canola is much more sensitive to seed-place fertilizer than corn or cereals.

3.2 Effect of combinations of ammonium sulfate and monoammonium phosphate on emergence and early season biomass

Addition of 15 to 30 kg P_2O_5 ha^{-1} along with the S application led to more injury represented by reduced seed germination/emergence and early growth of seedlings, than S alone at corresponding rates. Canola usually shows injury response to MAP alone at rates of 30 kg P_2O_5 ha^{-1} and higher (Qian and Schoenau 2010). However, decreases from addition of the

Cultivar	S						$S+15P_2O_5$						$S+30P_2O_5$					
	Kg S ha^{-1}						Kg S ha^{-1}						Kg S ha^{-1}					
	0	10	20	30	40	50	0	10	20	30	40	50	0	10	20	30	40	50
B. napus																		
Invigor 5440	100a	97a	92a	68b	57b	32c	100a	102a	82ab	76b	49c	24d	100a	100a	81a	81a	47b	32b
Victory 1037	100ab	99ab	93a	84abc	84bc	61c	100a	97a	88ab	81abc	79bc	67c	100a	89a	81a	79ab	69ab	63b
Victory 1040	100a	102a	106a	99a	65b	56b	100a	100a	93a	82a	60b	49b	100a	92a	85a	83a	58b	49b
HEAR	100a	95a	99a	95a	86a	65b	100a	98ab	100a	100a	84bc	72c	100a	90a	88a	88a	63b	61b
5525 Clearfield	100a	99a	93a	84a	84a	61b	100a	97ab	88ab	81abc	79bc	61c	100a	89ab	86abc	79abc	69bc	63c
74P00 LL	100a	98a	94a	80a	80a	24b	100a	83a	87a	59b	41b	37b	100a	56b	54b	42b	30b	34b
45H26 RR	100a	102a	100a	100a	84b	76b	100a	97a	94a	83b	84b	78b	100a	97ab	95ab	92abc	88bc	83c
B. rapa																		
ASC-7 B. rapa	100a	88ab	100a	89ab	63bc	40c	100a	65b	49bc	47bc	37c	29c	100a	61b	55b	55b	21c	27c
B. juncea																		
Xceed	100ab	100ab	109a	83abc	72bc	66c	100a	80b	90ab	80ab	72bc	50c	100a	89a	81a	94a	57b	53b
Dahinda	100a	89ab	103a	73bc	53cd	31d	100a	93a	70b	70b	40c	7d	100a	97a	59b	47b	22c	9c
Camelina sativa	100a	91ab	71bc	63c	23d	17d	100a	103a	63b	69b	50bc	25c	100a	47b	38bc	27cd	15de	9e
B. carinata	100a	99a	85a	99a	57b	46b	100a	98a	82ab	95a	67b	63b	100a	69b	62bc	59bc	36c	43bc

Numbers in a column followed by the same letter are not significantly different at $P<0.05$.

Table 3. Mean germination (percentage of unfertilized control) of *Brassica* species with seed-row applied AS and MAP.

	Plant tissue biomass (mg)																	
	S Kg S ha^{-1}						S+15P_2O_5 Kg S ha^{-1}						S+30P_2O_5 Kg S ha^{-1}					
	0	10	20	30	40	50	0	10	20	30	40	50	0	10	20	30	40	50
B. napa																		
Invigor 5440	78a	84a	76a	52b	44b	23c	64ab	71a	60ab	48bc	33c	14d	66a	68a	59a	53a	28b	18b
Victory 1037	72ab	78ab	90a	64bc	48cd	41d	79a	78a	79a	71a	54b	51b	68ab	70ab	76a	60bc	49cd	42d
Victory 1040	67a	67a	69a	69a	39b	36b	71ab	73a	64ab	55b	37c	27c	67a	61a	57a	56a	34b	25b
HEAR	55ab	53ab	56a	51ab	45b	33c	52ab	52a	56a	54a	43bc	36c	55a	52a	53a	50a	36b	34b
5525 Clearfield	55ab	59a	55ab	50b	47b	30c	64ab	72a	62ab	50bc	45cd	36d	67a	67a	57ab	53bc	40cd	37d
74P00 LL	52a	48a	37b	37b	34b	9c	49a	37b	31bc	23cd	14d	17d	52a	25b	26b	19b	15b	13b
45H26 RR	111a	117a	115a	104a	85b	72b	119a	105ab	93bc	82c	83c	64d	114a	108a	99ab	89b	83bc	73c
B. rapa																		
ASC-C7	18ab	20a	24a	17ab	11bc	6c	30a	16b	15bc	8c	10bc	9bc	30ab	22ab	37a	11ab	6ab	5b
B.juncea																		
8571	51a	53a	54a	44ab	32bc	28c	55a	42b	43b	34b	32b	22c	50a	46ab	34bc	46ab	25c	23c
Dahinda	24a	22a	26a	20a	10b	7b	22a	22a	16ab	18a	9b	1c	25ab	29a	16bc	8cd	4d	2d
Camelina sativa	11a	11a	7ab	6b	4bc	2c	11a	10a	6b	6b	4b	2b	11a	7b	5c	4cd	2de	1e
B. carinata	121a	105ab	69cd	85bc	44de	33e	131a	121ab	78cd	93bc	64cd	57d	133a	65b	51bc	36cd	27cd	23d

Numbers in a column followed by the same letter are not significantly different at $P<0.05$.

Table 4. Mean plant tissue biomass (mg) of 12 oilseed cultivars with seed-row applied AS and MAP.

MAP were typically smaller with the *B. napus* and *B. carinata*. The *B. rapa* and *B. juncea cv. Dahinda* appeared more sensitive to the addition of the P along with S. Among these, the *B. rapa cv. ACS- C7* was particular sensitive to P addition for both rates (15 and 30 kg P_2O_5 ha^{-1}). When AS alone was used, the injury in this cultivar was observed at AS rate of 40 kg S ha^{-1}; but the reduction of emergence with both rates of P addition was observed at AS rate of 10 kg S ha^{-1} (Table 3). For the two cultivars of *B. juncea*, the *Dahinda* cultivar was less tolerant to AS with MAP than *Xceed 8571* (Table 3). The seed sample from which the *Dahinda* was taken was two years old, which may have affected seed vigour and reduced germination. Seeds with lower vigour result in greater reduction in emergence (Canada Canola Council 2005).

Overall, while the high rate (30 kg P_2O_5 ha^{-1}) sometimes reduced emergence and biomass production compared to the low rate (15 kg P_2O_5 ha^{-1}), often the reductions were not large (Table 3) for most cultivars tested. This agrees with earlier findings that the adverse effect of MAP-P on seed germination and biomass of canola became pronounced at rates over 30 kg P_2O_5 ha^{-1} (Qian and Schoenau, 2010).

4. Conclusion

Rates of seed-row placed ammonium sulfate above 20–30 kg S ha^{-1} were associated with significant reductions in emergence and biomass of many *Brassica* species/cultivars. Addition of 15 – 30 kg P_2O_5 ha^{-1} MAP along with AS often caused further reductions in emergence and biomass, although these were generally not large with *B. napus* cultivars. Differences in tolerance to seed row placed S and P were observed among cultivars. The cultivar 45H26 RR was the most tolerant of cultivars tested, while the most sensitive to seed-row placed S and S+P were *B. rapa, B. juncea* cv. Dahinda, and *Camelina sativa.* Further study is required in the field to establish whether seeds grown under different growing conditions and soil types have similar responses.

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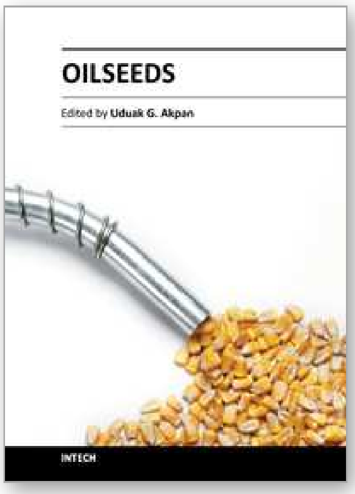

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